DLR‘s Free Piston Linear Generator FPLG

Development of an Innovative Linear Power Unit

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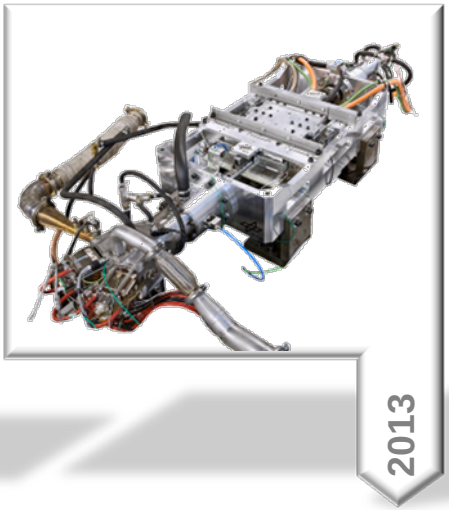
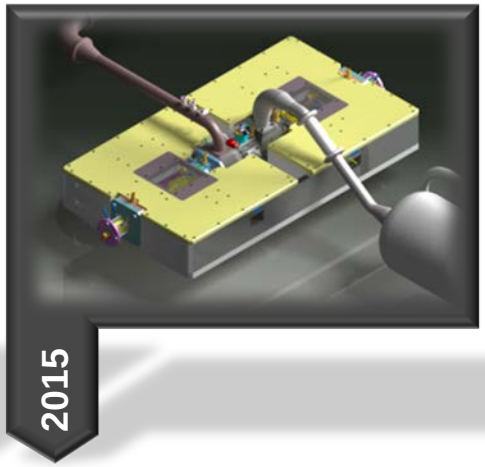
FPLG Project Overview

A Decade of Linear Power





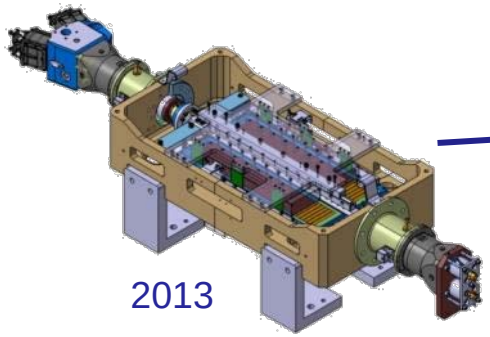
Idea & Concept → Simulation & Calculation → Implementation Subsystems → Implementation Overall System → Technology Development → Series Development → Market

Idea of the FPLG

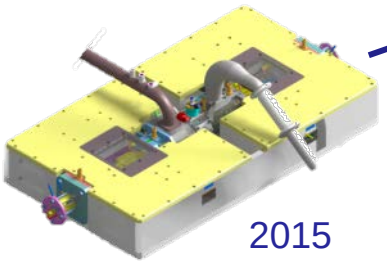
Electricity Generation Directly from Different Fuels

Idea of the FPLG

Free Piston + Linear Generator + Gas Spring

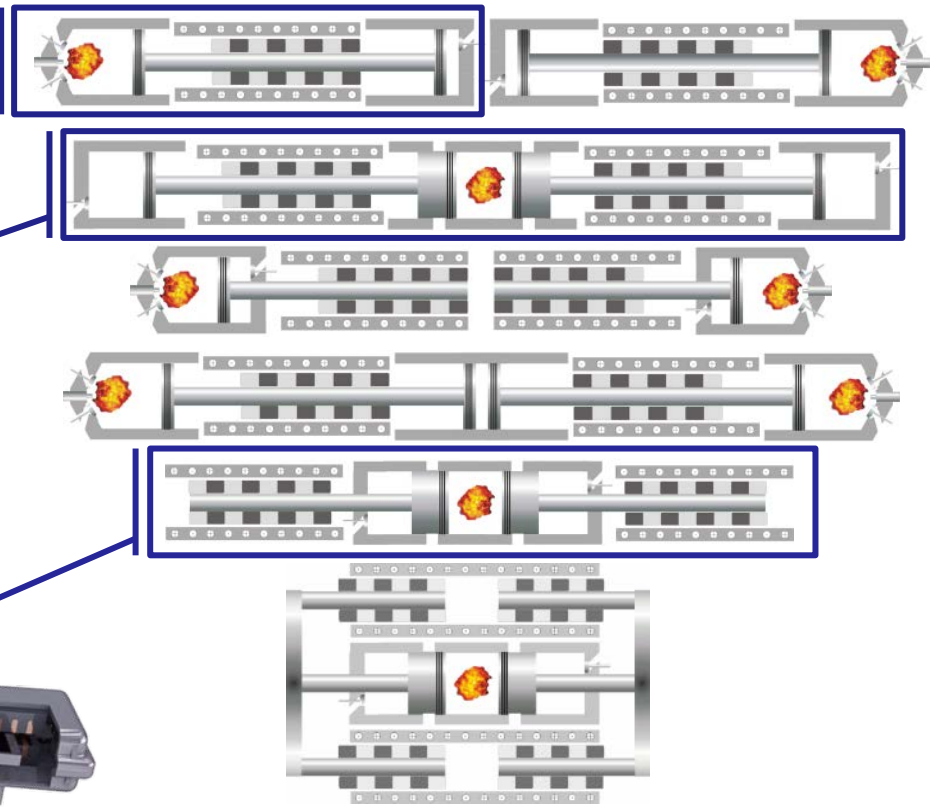


2013



2015

Concept study



Potentials

A combination of advantageous properties

Variable compression
Variable displacement
Variable piston movement

- High efficiency (43 – 47% indicated)
- Even at partial load
- Very good flex-fuel capability
- Online downsizing
- Controlled compression ignition (HCCI)
- All emission requirements fullfilled, includinng EU6

Simple design with no crankshaft

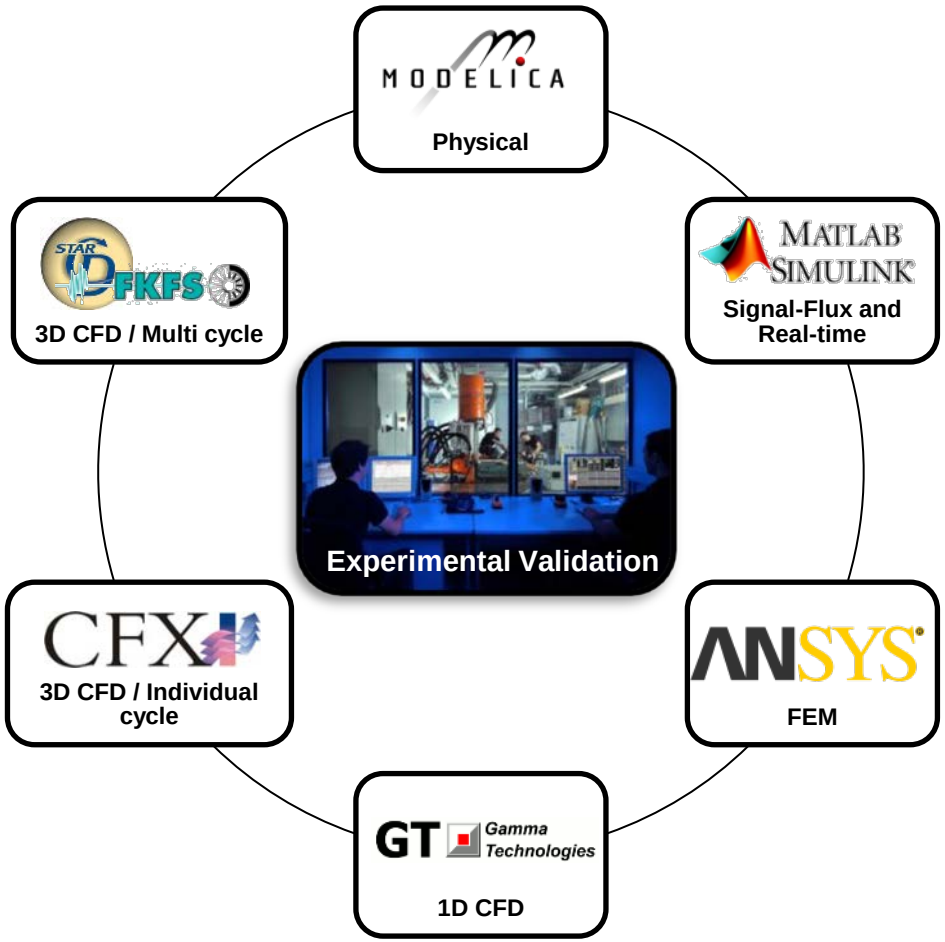
- Compact in size – only 15 cm flat
- Few parts, of which only a small number move
- No lateral piston forces
- Reduced friction and wear
- Great mass balancing/Quiet in operation

Modular in design

- Large quantities / small number of variants
- Low production costs (1400 € for a range-extender module)
- Complete cylinder cutoff
- Combined heat and power (CHP) possible
- Applications: energy, automotive and more

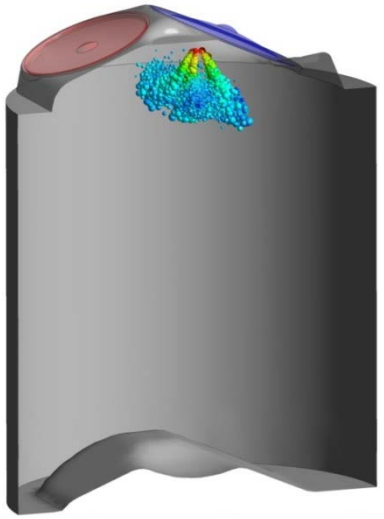
Simulation

Various Tools, various models

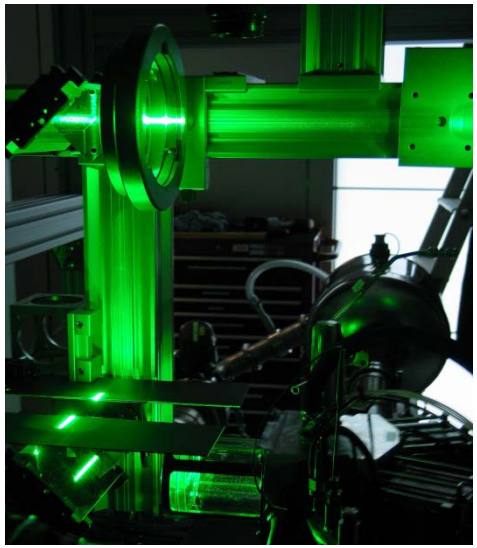


Validating the Simulation

Using laser optical methods

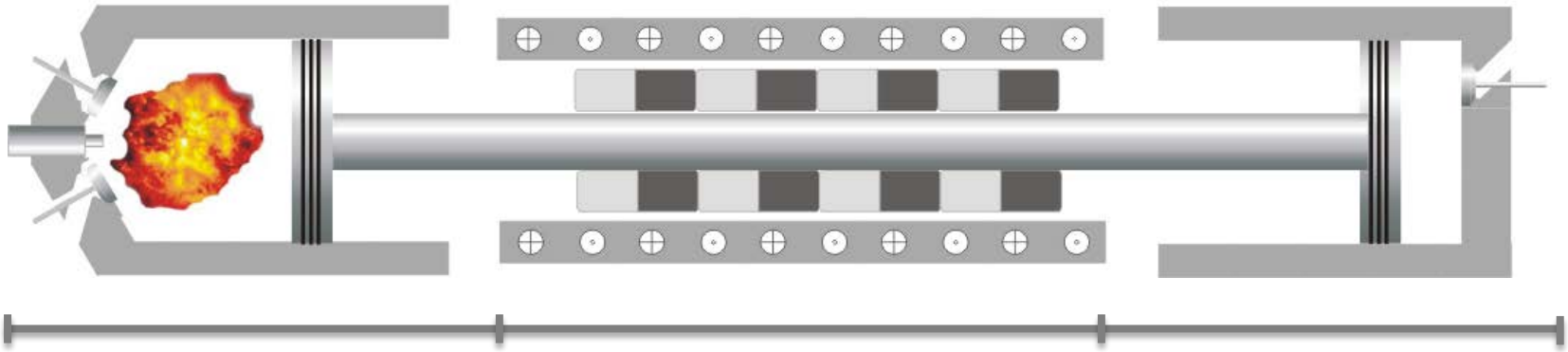


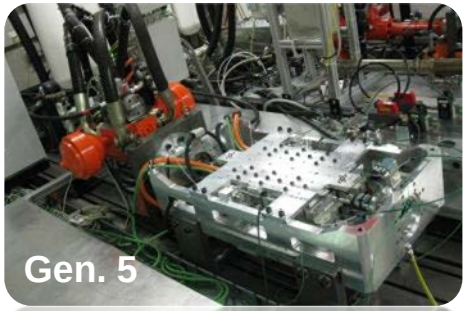
- Particle Image Velocemetry (PIV): Scavenging Process
- Laser Induced Flurescence (LIF): Mixture Formation / Combustion
- Experimental setup of the combustion unit:
  - 2 stroke DI Gasoline
  - Spark ignition or compression ignition (HCCI realized)
  - Until 2014 single combustion with head loop scavenging through electromagnetically actuated valves
  - 2015: Longitudinal port scavenging scavenging through ports



3 Subsystems

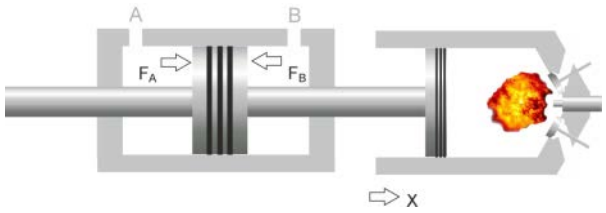
Developing them One by One

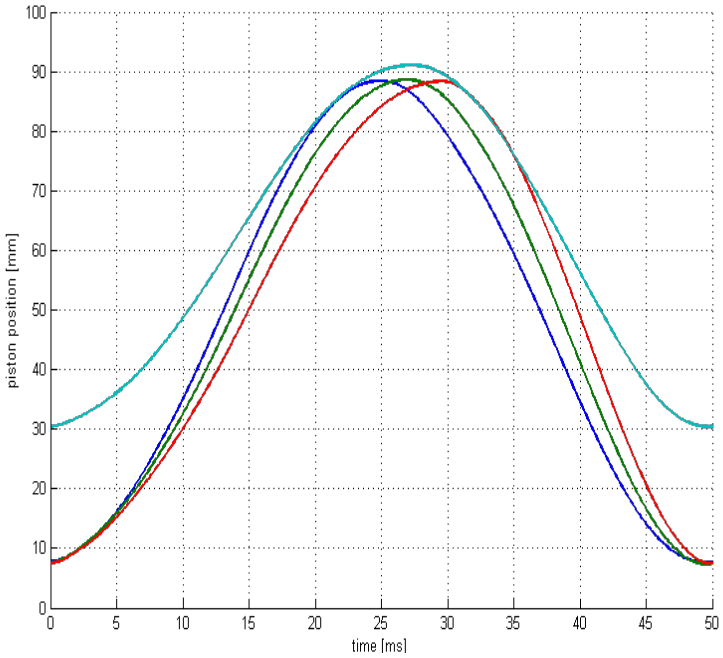


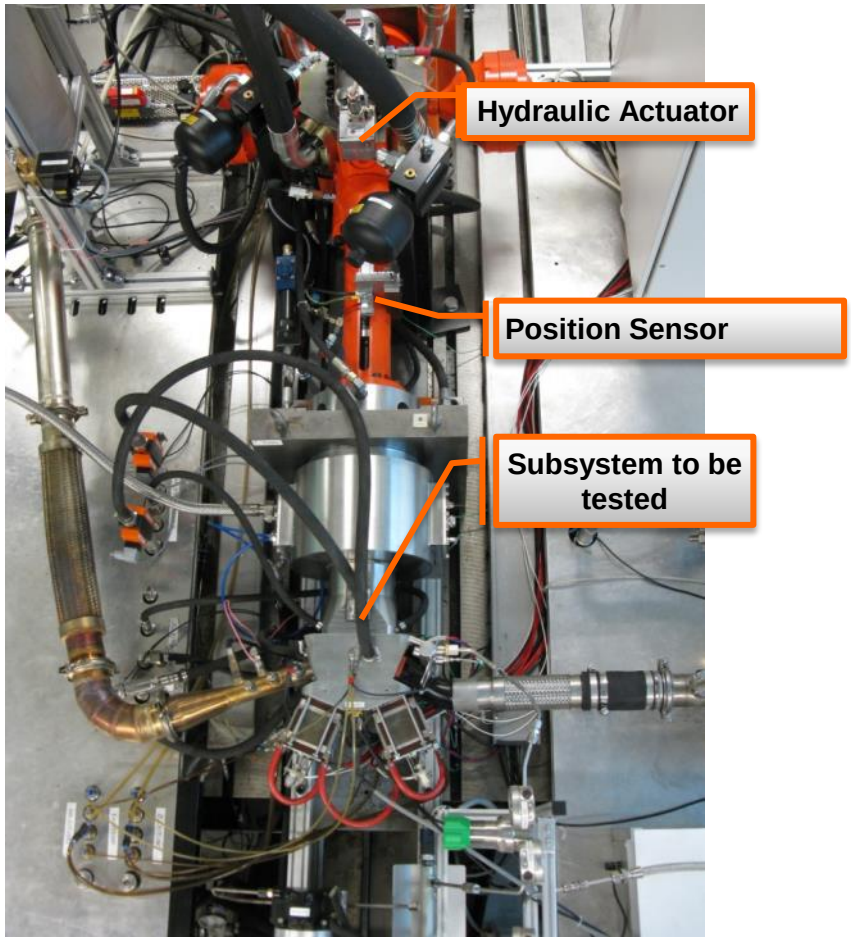


Developing the Subsystems

On a fully linear hydraulic engine test bench



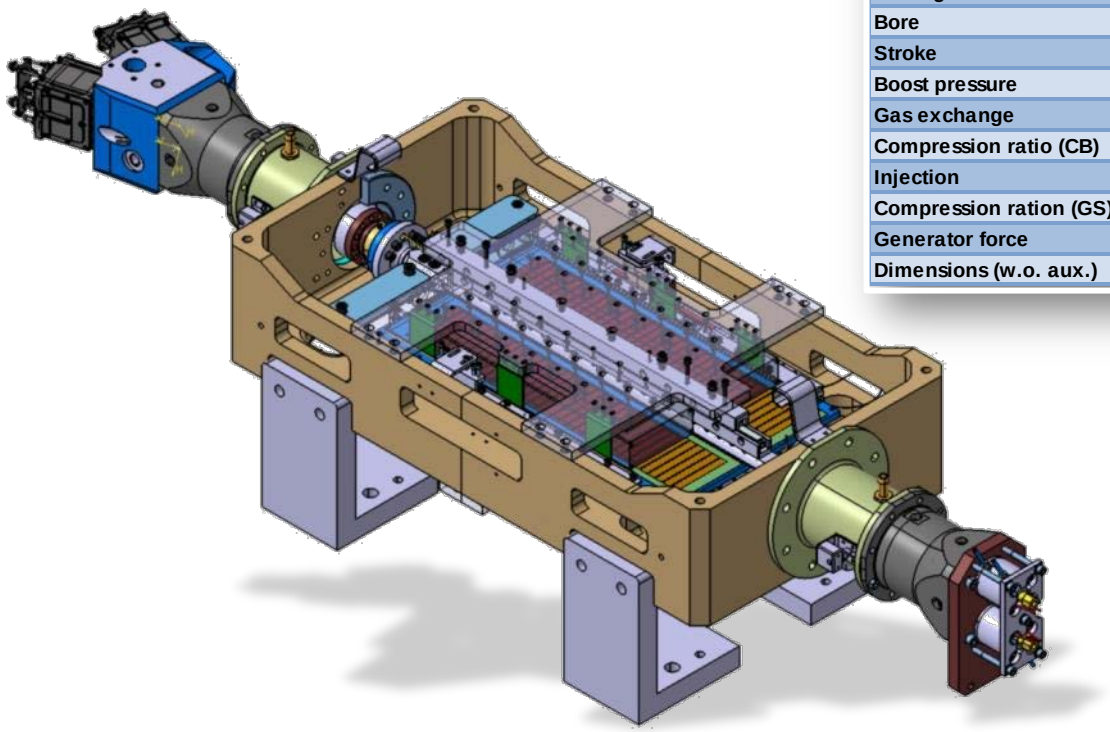




Overall System

Putting the subsystems together

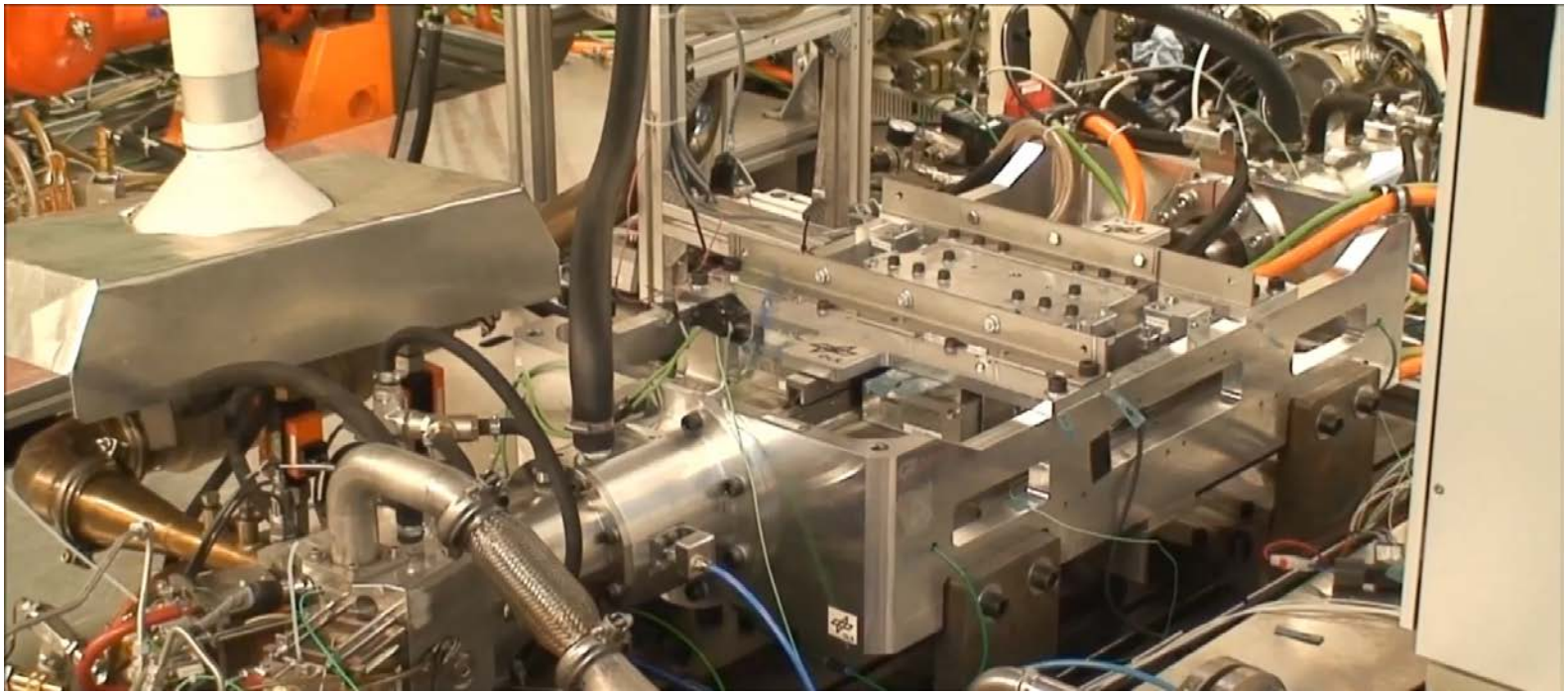
Constructive layout		1 combustion chamber, 1 linear generator, 1 gas spring
Combustion process		2 stroke spark ignition
Displacement volume	cm^3	321 - 481
Power (indicated)	kW	0 - 12
Operation frequency	Hz	16 - 21
Moving mass	kg	35.12
Bore	mm	82.5
Stroke	mm	60 - 90
Boost pressure	bar abs	0.2 - 1.0
Gas exchange		Loop scavenging (2 inlet valves, 1 outlet valve)
Compression ratio (CB)		7 - 11
Injection		Direct injection, central multi hole injector
Compression ration (GS)		2,5 - 15
Generator force	N	typical 4000, max. 12000
Dimensions (w.o. aux.)	mm^3	1940 * 500 * 225



- Proof of Concept 2013: Up to 8 kW_{el} @19.5 Hz
- World‘s first system in this design (CB-LG-GS)

Overall System

Ignition!

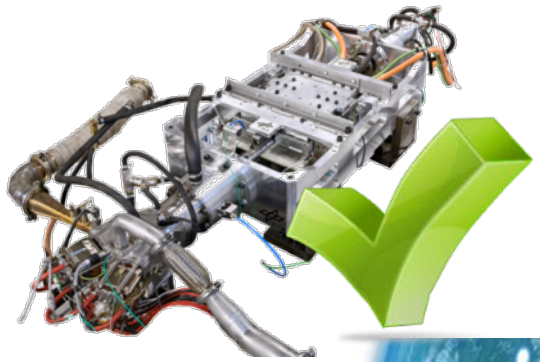


Technology Development

What‘s next?

Proof of Concept

- Simulation
- 3rd gen. combustion
- 5th gen. linear generator
- 7th gen. gas spring
- Hydraulic engine test bench
- Combustion processes
- Head loop scavenging
- Control
- Start up / shut down
- Safety algorithms

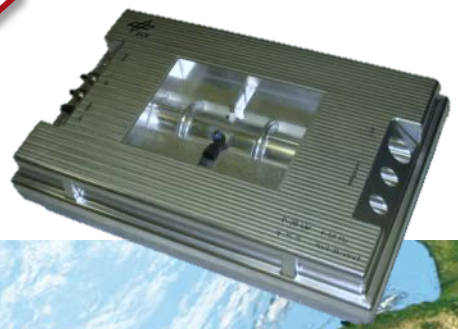


Prototype

2015

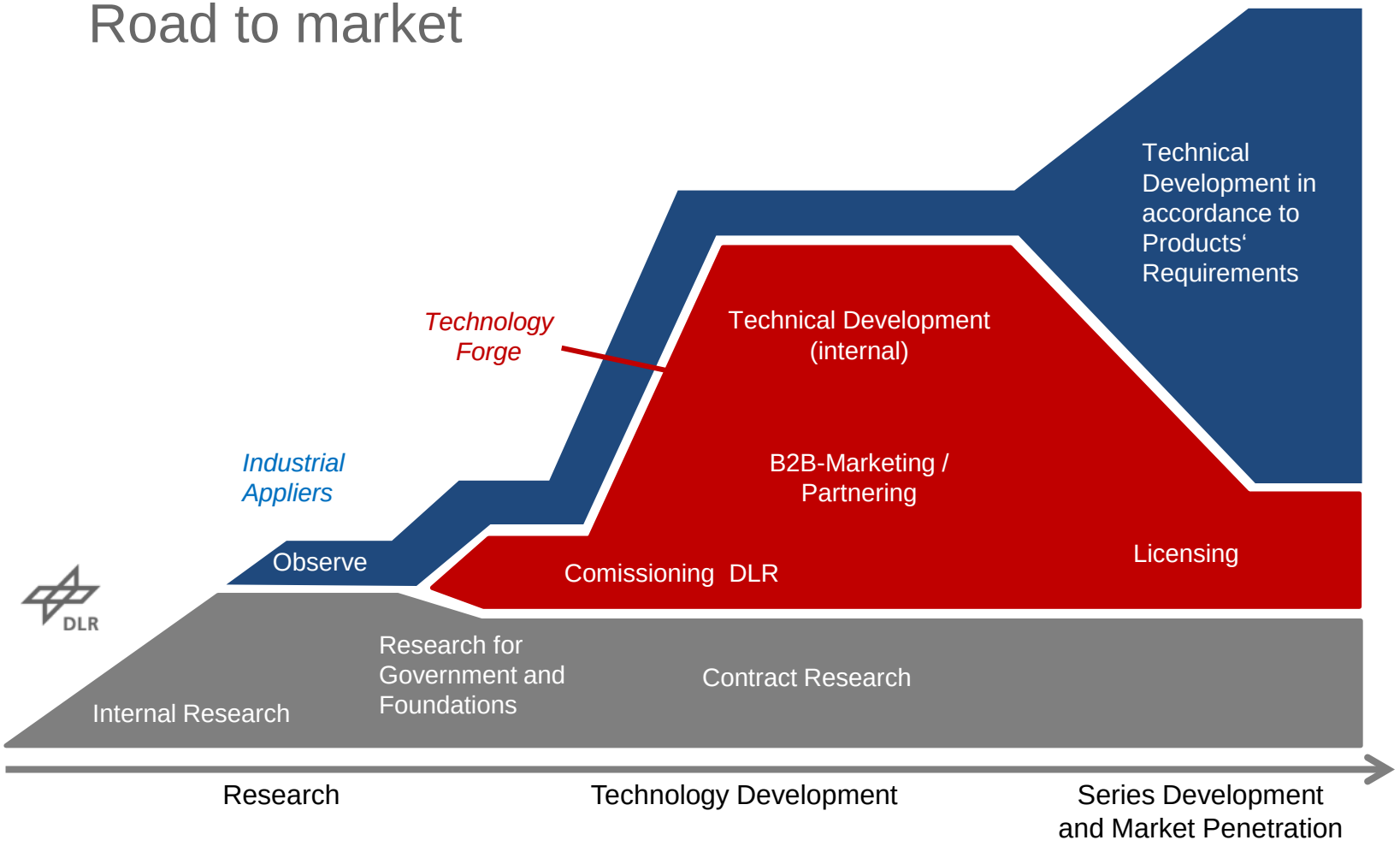
- Switch to opposed piston / longitudinal scavenging
- Synchronisation
- Combustion process optimization
- Piston tribology
- Bearings
- Supercharging
- Package
- Power electronics
- Increase of operating frequency
- Emissions
- Endurance

2018



Industrial Realisation

Road to market



Questions? Comments?

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